ISSN 0704-3716

Canadian Translation of Fisheries and Aquatic Sciences

No. 5227

Transport and storage of fresh fish. Excerpts from studies on containerization of lean fish

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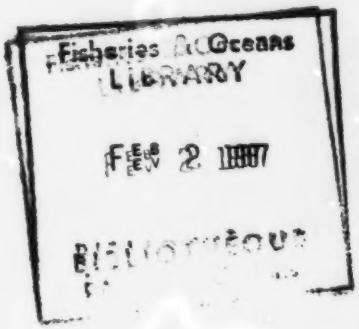
Original title: Transport og lagring av fersk fisk. Utdrag fra undersokelser vedrorende containertransport av mager fisk

From: Institutt for kjoleteknikk, NTH

Original language: Norwegian



Available from:
Canada Institute for Scientific and Technical Information
National Research Council
Ottawa, Ontario, Canada K1A 0S2

1986

29 typescript pages

Secretary of State | Secrétariat d'État

90-02682/

MULTILINGUAL SERVICES DIVISION – DIVISION DES SERVICES MULTILINGUES

TRANSLATION BUREAU | BUREAU DES TRADUCTIONS

Client's No.–N° du client	Department – Ministère	Division/Branch – Division/Direction	City – Ville
2111982	DFO	IPB	Ottawa
Bureau No.–N° du bureau	Language – Langue	Translator (Initials) – Traducteur (Initiales)	
	Norwegian - English	IEC	

TRANSPORT AND STORAGE OF FRESH FISH

Excerpts from studies on containerization of lean fish

Johnny Røyrvik

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Transport and storage of fresh fish.
Excerpts from studies on containerization of lean fish.

1. Background

The transport stage of fresh fish from time of catch to processing is a difficult problem, both because of the short time the fish will keep fresh, and because of other natural conditions that may occur during fishing. The type of container that is still used almost exclusively, i. e. boxes chilled with ice, is characterized by time-consuming manual labour. The operating economy also suffers, due to reduced utilization of raw materials and reduced product quality.

The problems found in fresh fish trawling are a good example. The heavy and clumsy loading/unloading forces the boats to deliver their catch directly to the factories. It is then only natural that each catch period is stretched to its limits in order to reduce losses. Table 1 shows the operating time, etc., of six fresh fish trawlers from Vesterålen. When the catch periods are pushed up towards 17-18 days*, the quality of the raw material is drastically reduced. About half of the load cannot be used for fillet production.

Based on these facts, studies were begun at the Institute for Refrigeration Engineering at the Technical University of Norway, with the goal of contributing to the development of better methods of handling fish.

* Transl. note: In this document "day" always means 24 hours.

	Mean	Standard deviation
Number of operating days	226.6	82.3
Number of fishing days	173.9	64.3
Number of trips	15.0	5.2
Operating days per trip	15.0	1.3
Operating days less fishing days/trip	3.5	0.1
Value of catch per fishing day in Norwegian crowns	18,582.-	3,507.-

Table 1 Operating statistics for six fresh fish trawlers, Vesterålen, 1977.

2. Mini-containers as load units

The principles and methods that have proved advantageous for other types of transport, should as much as possible also be applied to the handling of fresh fish. The goal is to combine efficient and flexible forwarding of the raw material with acceptable investment costs.

Various types of containerization are becoming increasingly common in areas where mechanization has to be combined with a smooth distribution of goods. This type of cargo transport, when adapted to natural conditions, also seems to offer the best system for transport/storage of fresh fish. For a large part of the fishing industry it may be necessary to separate the transport from the actual fishing activity on different ships. An efficient container system can make such a transshipping profitable in many cases.

It appears reasonable to assume that the correct size of the load unit will vary with type of ship and catch. The highest possible degree of standardization is preferable, both with respect to investment costs and flexibility within the transport systems. Based on these and other ideas, the correct container size was assumed to be about 1 m^3. The containers could then be adapted to most of today's ships and other transport equipment.

It is assumed that the fish will continue to be refrigerated with ice produced in plants on land. This will be the cheapest method, primarily because a large land-based plant provides better utilization of the machinery. On large fishing boats, e.g. trawlers, the heat leaking into the hold is usually absorbed by an installed mechanical refrigeration unit, since this is a relatively low but even load.

"The fresh fish regulations" give 60 cm as maximum height for icing in bins. However, already at this height, the fish become considerably deformed*, and drained stacking also results in weight loss. When (2)
containers are used, a system of mixing water with the fish and ice will be suitable. The water will then take on a double function:

a The pressure is equalized

b The water can contribute to the heat transfer from fish to ice through convection. More contact surface between fish and refrigerant (ice-water) will also improve the refrigerating capacity.

* Transl. note: Here it is possible that one line was cut off during photocopying, see note on page 7.

The choice is between fresh water and sea water (possibly fresh water with salt added). Sea water would, of course, be the most convenient method during ocean fishing. Fresh water, however, is the most practical when the containers are to be filled on land, or for fishing in unclean waters.

In the studies these two alternatives were compared to regular box storage. Three parallel methods were also used:

I Containers chilled with ice + sea water (CSW - chilled sea water).

II Containers chilled with ice + fresh water (CFW - chilled fresh water).

III Boxes with ice (here called ICB - ice-chilled box).

3. Experiments

Figure 1 shows the normal treatment of the main portions, while Figure 2 shows analyses performed on test pieces. The work includes four full series, as shown, plus additional test series, most of them concentrated on refrigerating capacity. The studies can be divided into three main areas, as shown by the figure:

a Temperature conditions during storage

b Weight yield from catch to consumer-ready product

c Quality of the fillet product

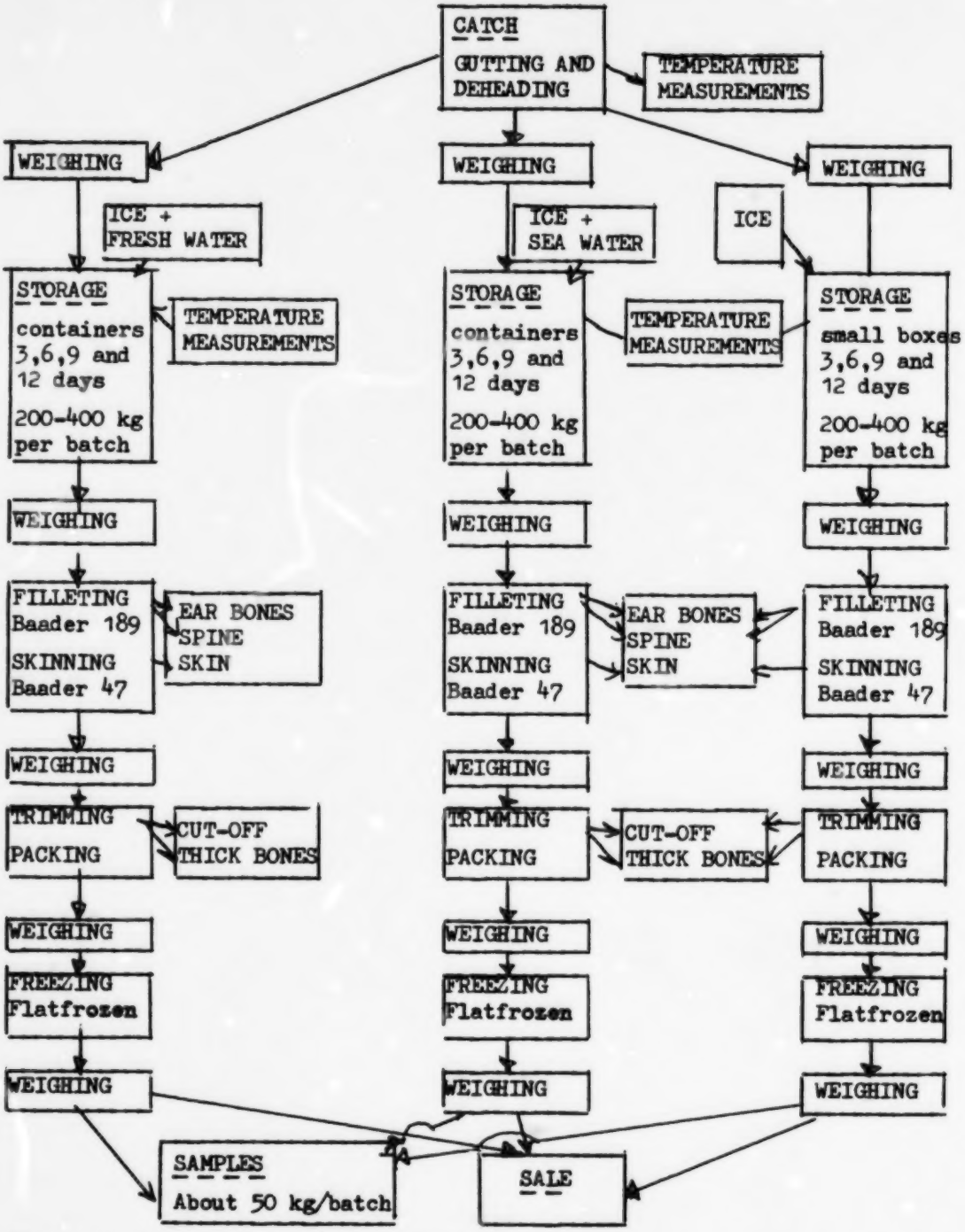

Figure 1 Diagram of treatment of main parts.

In addition, more sporadic measurements were taken, e.g. measurements of bacteria before and after ...*

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* Transl. note: Line(s) cut off during photocopying. Complete copy of original not made available to me.

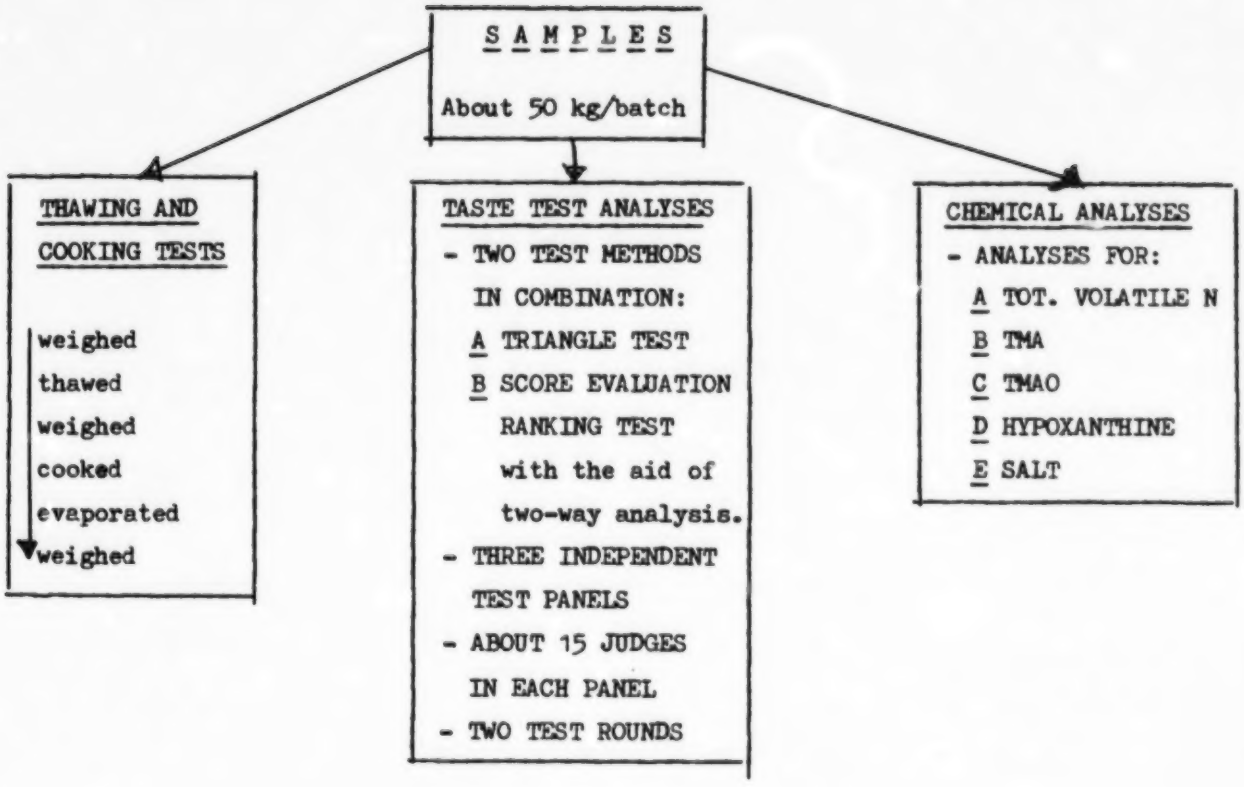


Figure 2 Analyses performed on samples from the test batches.

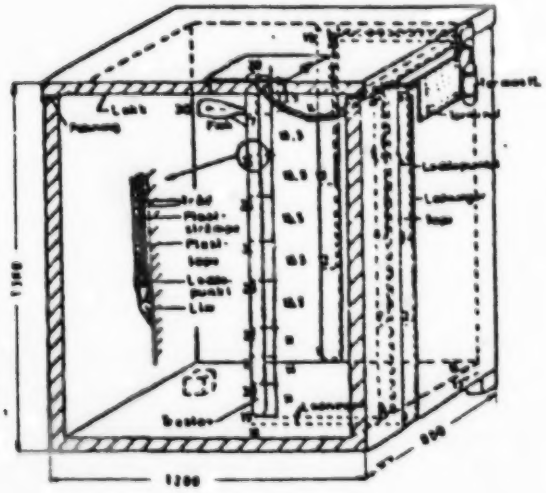


Figure 3* Location of thermoelements on fiberglass container.

In some tests, as many as 17 thermoelements were placed on the centre rod.

* Transl. note: Text on figure unreadable on my photocopy.

The containers

In the first two series, commercial brand containers were used for the storage/transport tests. However, these models do not have thermal insulation and their design made them somewhat unsuitable for use on boats. Specially built containers[1*] were therefore used for the remaining test series. Two versions of these were built: One was made of fiberglass-reinforced plastic, the other of aluminum. The containers had double walls with 2.5 - 3 cm of polyurethane in between. If a container is to be suitable in a variety of situations, insulation becomes almost a necessity, obviously more so the higher the room temperature is and the slower the water circulation in the container.

Figure 3 shows a sketch of the fiberglass container and where the thermoelements for the temperature measurements were placed. This was the most used and best insulated container type. It turned out, however, that all the containers that were of an experimental design, had defects in the form of thermal bridges, which reduced their insulation properties. The fiberglass containers had a high cold penetration in the bottom around the legs, and also around the drainage outlet.

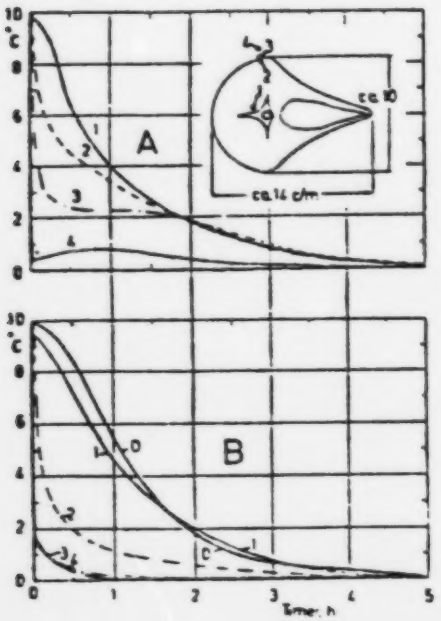
1* Transl. note: This note, which must appear on the original, was cut off during photocopying, see my note on page 7.

4. Temperature conditions during storage

The quality level of fish after a given storage time is normally determined mainly by how the temperature fluctuates. The temperature response that is considered as most favourable, is one where chilling is as rapid as possible, followed by storage at the temperature where freezing begins (the freezing point).

The chilling time is determined by the temperature at time of loading and the refrigerating capacity. The highest refrigerating capacity would probably be achieved if the fish were surrounded by a refrigerant with an unlimited heat absorption capacity. In such a case, the temperature response would be determined only by the thermal conduction in the fish body. It would be possible to come close to this theoretical optimum condition, if each fish was packed in finely crushed, drained ice, provided that its entire surface was in contact with the ice. (4)

Figures 4 A and B show measurements from the chilling of two 4 kg fishes in ice (A) and in ice + fresh water (ice-water, B). Figure A shows that during icing, an insulating layer of air was quickly formed above the fish. The chilling process in the centre of the fish, however, was fairly similar in the two tests, the half-time for chilling (the time it took to reduce the temperature difference between fish and ice by half) was a little less than one hour. The "0" curve in Figure B shows the calculated temperature response



Figures 4 A and B Temperature as a function of storage time in two similar fishes (cod).

A - packed in drained ice

B - chilled in ice + water

Gutted and deheaded

Weight of each fish: 4.0 kg

Width and thickness of largest part of fish, as shown in the figure.

Circumference: 40 cm, length: 70 cm.

Measuring:points:

1 - at the spine

2 - just below the skin

3 - on the skin

4 - about 5 mm above the fish

Curve "0" in Figure B shows calculated temperature response at centre of a cylinder with a 10 cm diameter. Instantaneous external chilling to 0°C. Thermal diffusivity : $4.7 \times 10^{-4} \frac{m^2}{h}$. Calculated according to (9).

---

at the centre of a cylinder with a diameter similar to the width of the fishes (10 cm), when it was chilled instantaneously on the outside to 0°C. The curve confirms that it is primarily the internal thermal conduction that determines the chilling time in both A and B.

A refrigerating capacity similar to the one shown in Figure 4 can be achieved with a container system, if, for example, plenty of ice is evenly distributed in the load. A system where the ice is finely distributed can also be useful in practice, especially if boats and transport stages are planned from the beginning. However, in cases where the transport system has to be developed to suit presently common boat interiors, being able to concentrate the ice more, would mean easier and/or less heavy work. The most convenient system would be one where all the ice could be placed under the fish. The ice could then be filled into the containers when they are loaded on board.

What level of the ideal process would be acceptable in practice, will have to be determined by balancing practical/economical considerations against losses in quality. The conclusions drawn further on are based on such evaluations which are, of course, fairly arbitrary.

The thermal conductivity of fish (and water) is poor, in the order of 0.5 W/mK. Therefore, in order to increase the heat transfer distances (the distance between ice layers), cooling must be ensured through convection in the water.

Convection can be brought about by:

a Differences in the specific weight of the water as a result of temperature or salt gradients (gravity flow), supplemented by:

b Pumping or agitation.

The study showed that when circulation is produced only through gravity flow, the recommended distance between ice layers becomes very limited. Figures 5 and 6 show temperature measurements in CSW and CFW, respectively, where the ice was placed in three layers separated by a distance of 30-40 cm. Although the effects on the temperature response of all conceivable parameters have not been calculated, the conclusion drawn was still that the greatest permitted distance between ice layers, at normal starting temperatures, would be approximately as shown in the figures.

On a boat, the motion of the sea results in increased agitation. In all the on board tests, the entire ice quantity was placed below the load, which had a height of about 1 m. In one case, the measurements shown in Figure 7, refrigeration was somewhat slower due to particularly calm seas. Therefore, circulation was increased by blowing air into the bottom of the containers, immediately into the fresh water container, and after about 20 hours into the sea water container. This system worked efficiently, even though the equipment used was of the most basic kind. Additional ice consumption was also minimal, estimated to about 0.5 kg/24 hours.

The movements on a boat are usually composed of many elements, from long, pitching movements to engine vibrations. The most important element, however, is * .....* width in meters and a deflection of (6)
10-15°. In order to measure the effects of rolling under controllable conditions, a simple cradle was constructed. It swang the containers harmonically around the centre of gravity with adjustable deflection and frequency.

* Transl. note: Line cut off in photocopying?

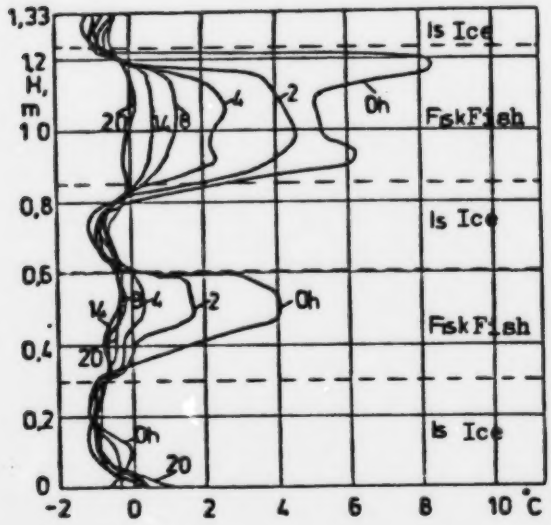


Figure 5 Temperature profile of the height in the container at indicated hours after test start, CSW.

Ice distribution at start, as described; distance between ice layers about 30 cm at the bottom and 40 cm at the top.

Salinity of water when loaded: 3.4 %

Starting temperature of sample fish/water/ice in °C: 11/6/-15.

Loaded quantities of fish/water/ice in kg: 440/170/260

Number of measuring points: 18.

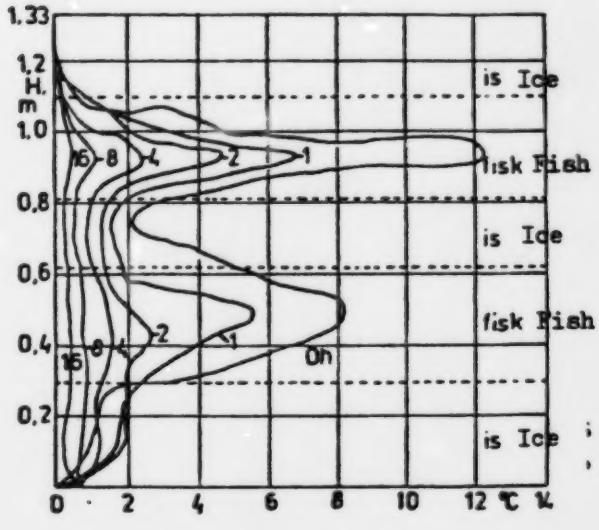


Figure 6 Temperature profile of the height in the container at indicated hours after test start, CFW.

Measuring points: 18, vertical centre of fiberglass container.

Temperature on loading of fish/water/ice in °C: 18/7/-15

Ambient temp.: About 20°C

Loaded quantities of sample fish/water/ice in kg: 400/280/165.

Ice distribution at start, approximately as indicated in the Figure.

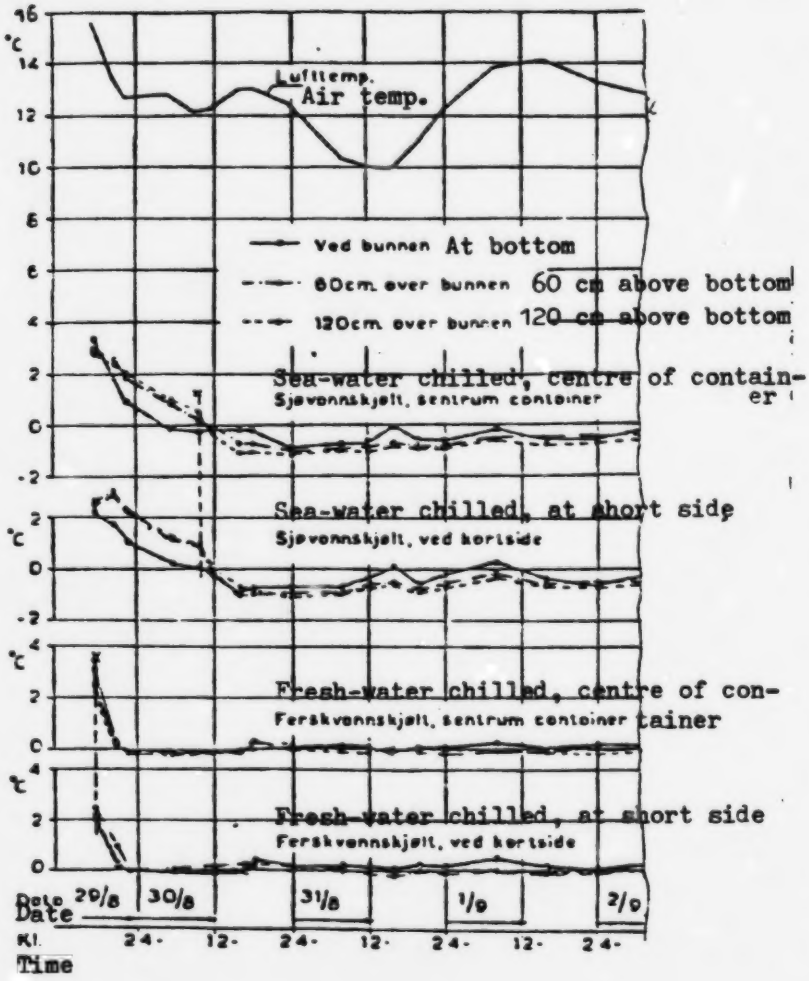


Figure 7. Temperature measurements from series no. 4, on trawlers.

X Forced water circulation with the aid of air injection.
Injection started immediately in CFW, after about 15 hours in CSW.
More ice was gradually added during storage.

Figures 8 and 9 show tests where the containers were swung at a frequency of 6 $min.^{-1}$ (normal width of a fresh fish trawler is approximately 10 m) and a deflection of 10^{o}. Even though, also in this case, there are many factors that may effect the temperature response, the amount of movement necessary seems to be of this magnitude both for CSW and CFW.

Due to variations in water density with temperature and salinity, it is always important that the ice remain below the fish. To ensure this, fish can be loaded before water, or a grating or similar device could be used.

In the reference method, boxes with ice, the temperature response varied greatly, from relatively good conditions when the work was carried out carefully, to completely unacceptable conditions. The open and uninsulated boxes were also very sensitive to the air temperature, Figure 10.

5. Weight yield from catch to consumer-ready product

Figures 1 and 2 showed the procedure for the yield measurements. Figures 11-15 represent the test results from four of the processing stages. In Figures 12-14, the unfilled markings represent studies where apprentices did the final trimming and packing. After trimming, these studies resulted in lower weight than the others, where the conditions were completely realistic (performed in regular production lines).

The main conclusion is that the fish increases in weight when stored in water. The weight increase is the highest in CFW, and can be significant alreay after a few days, Figure 11. The water that is absorbed, however, is only loosely bound, so that the differences in relation to the loaded quantity become smaller with each processing stage, Figure 15.

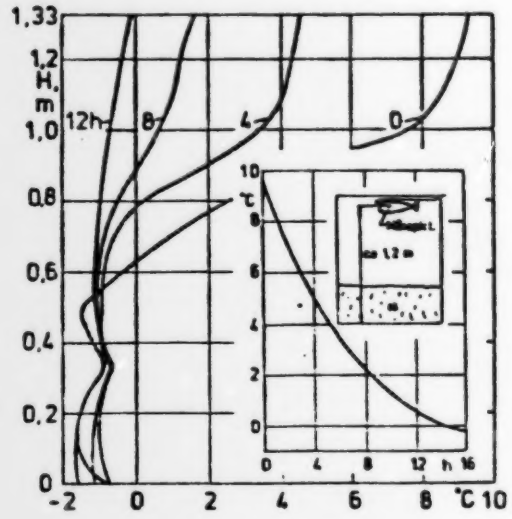


Figure 8.

Chilling of coal fish caught with lines: CFW. The inserted diagram shows measurements from one individual fish placed about 15 cm below the surface, weight 4.1 kg.
Starting temp.: Fish/water/ice in kg: 9/14/-2.
Ambient temp.: About 14°C.
Quantities of fish/water/ice in kg: 480/155/190.
Height after loading: About 50 cm.

Rolling motion in "wave simulator", frequency/deflection: 6 min^{-1}/10°.

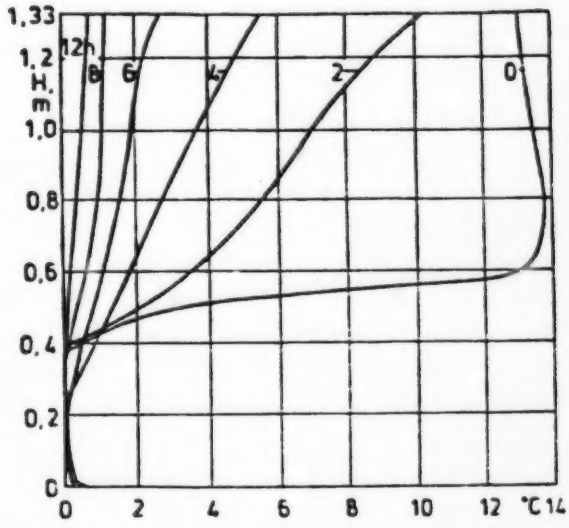


Figure 9.

Temperature profile of the height in the container at indicated hours after test start, CFW.
Rolling motion, frequency/deflection: 6 min^{-1}/10°.
Starting temp.: Fish/water/ice in °C: 15/12/-20.
Quantities of loaded fish/water/ice in kg: 490/170/154.
Height above the bottom at start: About 57 cm
Ambient temp.: About 20°C.

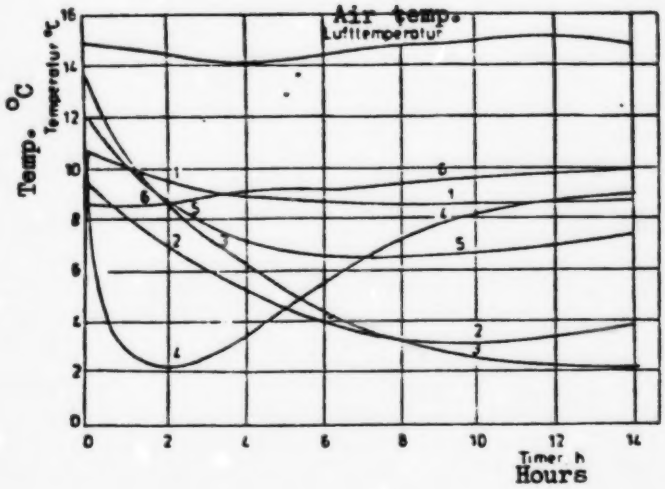


Figure 10.

Temperature measurements in fish stored in boxes with ice in an unrefrigerated raw material hold.

The ice was loaded in the manner it is normally done in reality: One layer below the fish and one above. The fish becomes exposed along the side very quickly.

Location of measuring points, 4 boxes in all:

1- In a box at the top, loose by side edge
2- In a large fish (5.5 kg) placed by side edge
3- At centre of box, loose against the wall
4- By the short side, loose against wall
5- As 4, opposite side, loose against wall
6- By the long side, loose against wall

<u>These measurements were performed apart from the regular test batches.</u>

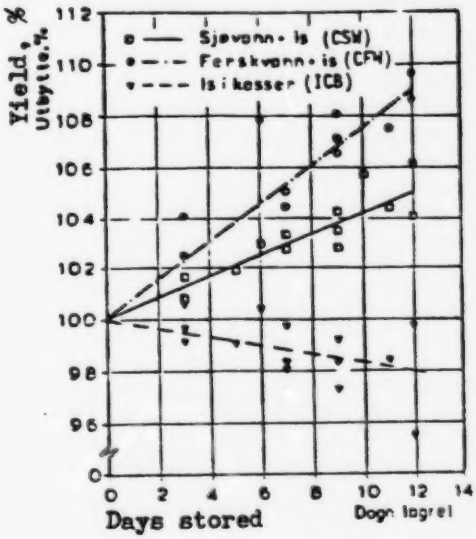


Figure 11.

Weight increase as a function of storage time.

The yield is calculated in relation to the recorded weight of gutted and de-headed raw material.

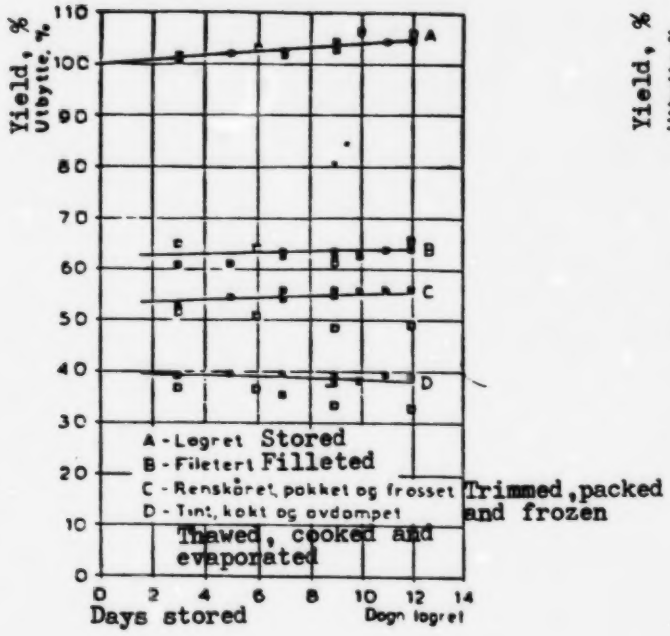


Figure 12.

Yield as a function of storage time for fish stored in sea water - ice (CSW). Yield in relation to gutted and deheaded raw material.
Unfilled markings - apprentices trimmed these batches.

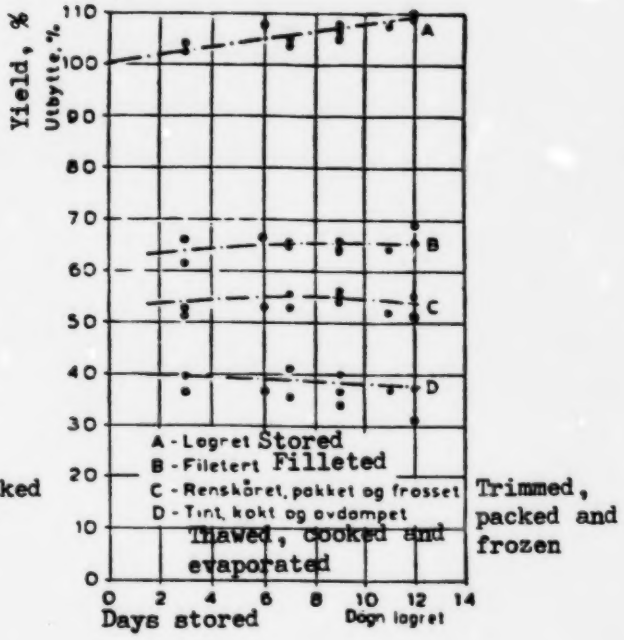


Figure 13.

Yield as a function of storage time for fish stored in ice-chilled fresh water (CFW). Yield in relation to gutted and deheaded raw material.
Unfilled markings - apprentices trimmed these batches.

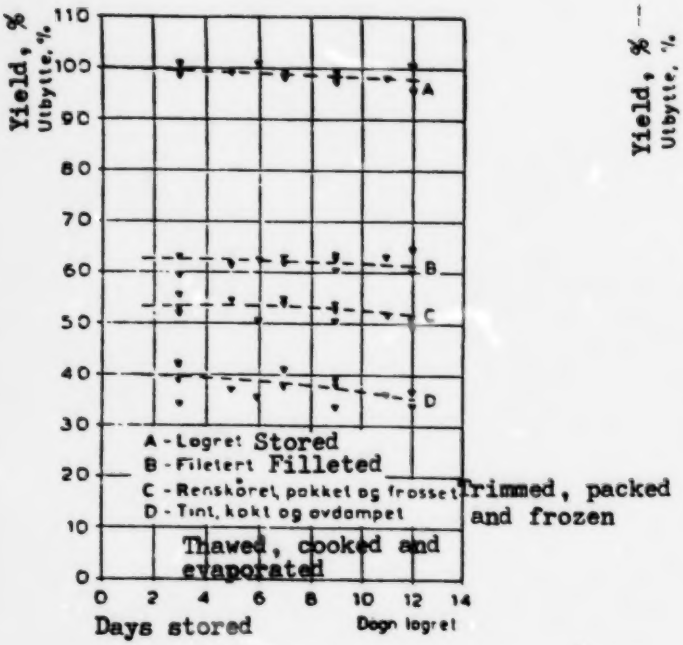


Figure 14.

Yield as a function of storage time for fish stored in boxes with ice (ICB).
Yield in relation to gutted and*

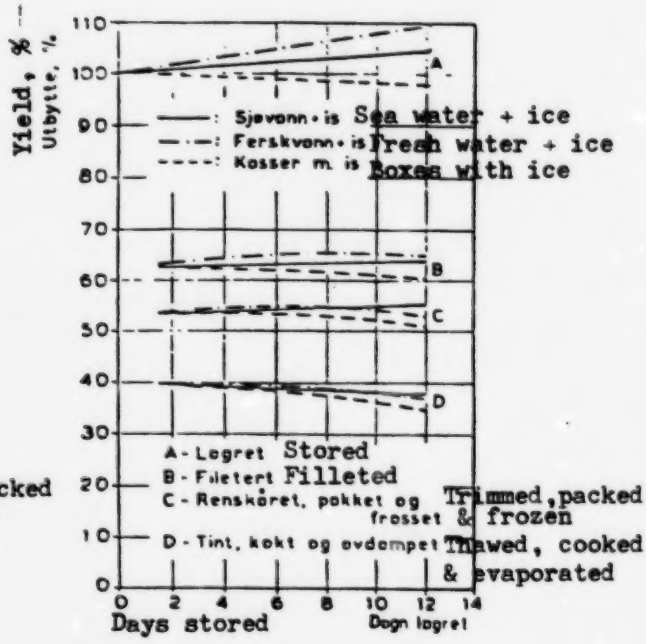


Figure 15.

Comparison of the curves shown in Figures 12-14.

* Transl. note: Lines cut off during photocopying

6. The quality of the fillet product

Taste test analyses

The principal attempt to determine the quality of the fillet product involved taste testing by a test panel. Extensive efforts were made in order to be able to demonstrate, with the highest degree of certainty, any possible differences in quality resulting from the three storage methods. With the help of three independent panels of judges, each consisting of 10-16 persons, samples from each test batch were tasted and judged approximately 240 times.

The analyses were performed through a combination of a triangle test and allocation of points according to a character scale. The scores were used both to make a simple comparison of the mean values, and as a basis for differential tests (the so-called Tukey's ranking test). This comparison of two different differential tests (the triangle test and Tukey's test) was desirable partly because possible differences in quality within each test batch could jeopardize the analyses.

For a more detailed discussion of the tests and the statistical methods used, we refer to reference materials 1 and 3. We will here only mention the main results.

Table 2 shows the results of the differential tests for one of the test series (series 3). In this series, the tests produced one of the most clear-cut results: Fresh water fish (CFW) is fairly

systematically separated from CSW and ICB after 9 days' storage (in particular by panel no. 1).

Storage time Days	Panel No. 1				Panel No. 2				Panel No. 3			
	Rank. t.		Triangle t.		Rank. t.		Triangle t.		Rank. t.		Triangle t.	
	Round no.		Round no.		Round no.		Round no.		Round no.		Round no.	
	1	2	1	2	1	2	1	2	1	2	1	2
3	A/C		B/C			B/C	A/C					
6	A/B	A/B A/C	A/B	B/C	B/C						A/C	
9	A/B	A/B B/C	A/B B/C	A/B B/C		A/C		A/B B/C		A/B B/C	B/C	A/C
12						A/C	A/B B/C	A/C B/C	B/C			

Table 2. Significance from differential tests. (ranking test and triangle test).

Test series no. 3

A - fish stored in sea water + ice (CSW)
B - fish stored in fresh water + ice (CFW)
C - fish stored in boxes with ice (ICB)

Three independent test panels, 10 judges in panel no. 2. 15 judges in the other two.

Two test rounds with fillet, frozen and then cooked.

Level of significance: 5 %
The markings show the tests where the types of fish were significantly different.

Figure 16 shows mean characters from the same panel of judges and the same series as a function of storage time. Figures 17 and 18 show the results of two other test series (series 1 and 4). The first thing we notice is that the change in quality in relation to storage time does not stand out clearly, but then, of course, the emphasis was on a comparison between the three storage methods after equal storage times. The scale was also perceived differently by the panels of judges, in particular by panel no. 3, see Figure 18.

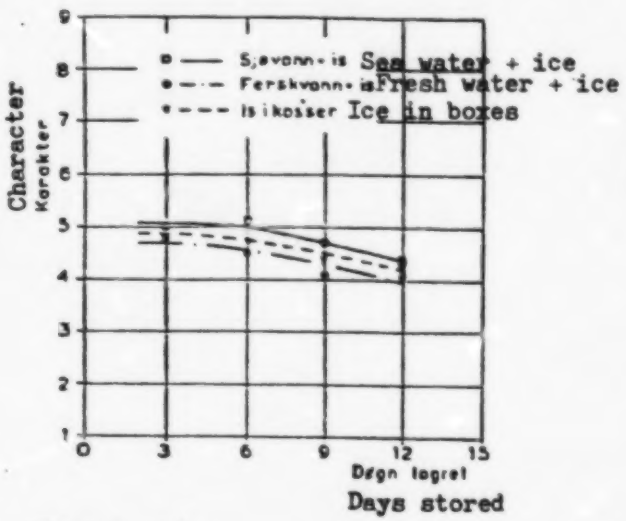


Figure 16.
Characters from taste tests of frozen and then cooked fillet as a function of the storage time of the raw material.
Mean characters from panel no. 1 in test series 3.
Comparisons between the three different storage methods.

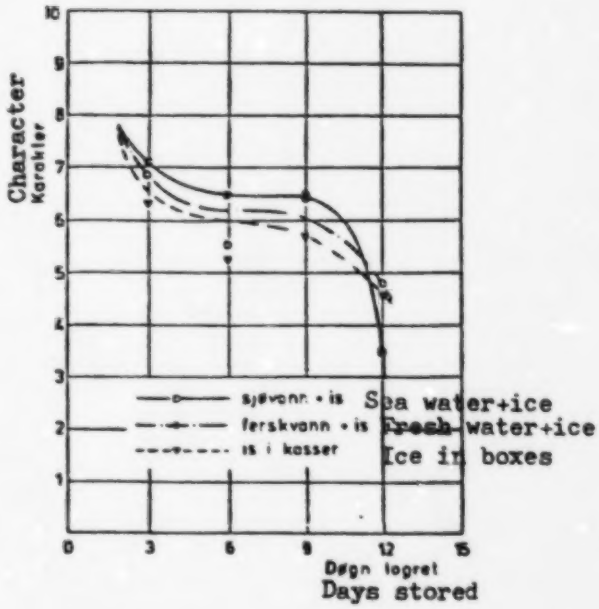


Figure 17.
Characters from taste tests of frozen and then cooked fillet as a function of the storage time of the raw material.
Test series no. 1, panel no. 1.

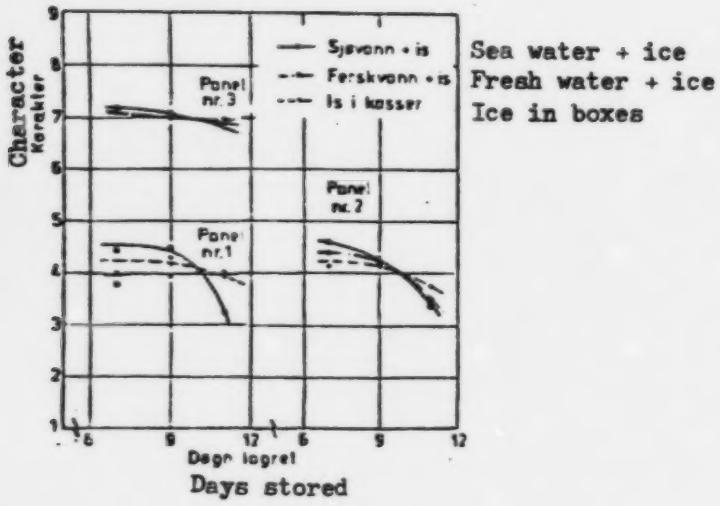


Figure 18. Characters from taste test of frozen and then cooked fillet as a function of the storage time of the raw material. Test series no. 4. * .....*

The main conclusion after the taste tests is that the differences in quality were generally small; the differences were particularly small before 8-9 days, which must be considered the longest acceptable storage time for high quality raw material. (12)

The general tendency seen in the scoring results is that sea-water stored fish often gets the highest score, while the fresh-water stored often gets the lowest. However, as will be shown later, the chemical analyses do not support the downgrading of the CFW fish. Neither were these fillets found to have a bad taste - the comments made were rather about a lack of taste, a certain tastelessness.

* Transl. note: Line(s) cut off in photocopying.

The tendency for the CSW fish to obtain the highest score was fairly general within the 8-9 days mentioned. In two of the series (series 2 and 3), this tendency persisted after the longest storage times, 10 and 12 days, respectively. However, in the other two series (series 1 and 4), it was the sea-water fish that had lost most in quality at the end of the test period, 11 and 12 days. Even if it is possible to demonstrate particular connections between cause and effect (such as lacking or unsatisfactory insulation), the final impression remains that storage in sea water, beyond the mentioned 9 days, is not advisable. If the quality losses during the freezing stages are also taken into consideration, it appears that one week is a reasonable upper limit for the storage time, regardless of the refrigeration method.

In series 1, the taste tests were also performed after one year of freezer storage. At that point, no systematical quality differences could be found.

Chemical measurements

The value of chemical quality measurements is, naturally, entirely dependent on the relationship between the chosen criterion and the overall quality level of the product. In these studies, the measurements were concentrated on the most common criterion: The decomposition of volatile nitrogen. Figure 19 shows, as an example, a comparison of measured contents of trimethylamine (TMA), as a (13)

function of the storage time. Although the spread is large, individual tendencies can be discerned. The CSW fish often has the lowest TMA content. This result is different from those produced by the taste tests, since this low content ought to guarantee the highest quality. The impression is that decomposition of nitrogen is not quite suitable as a criterion for quality, at any rate not for relatively fresh fish.

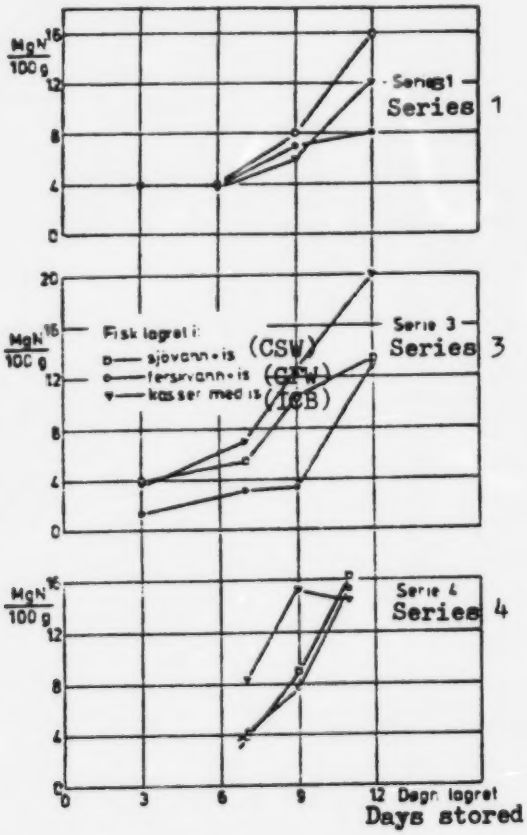


Figure 19. TMA content in fillet samples * .....*

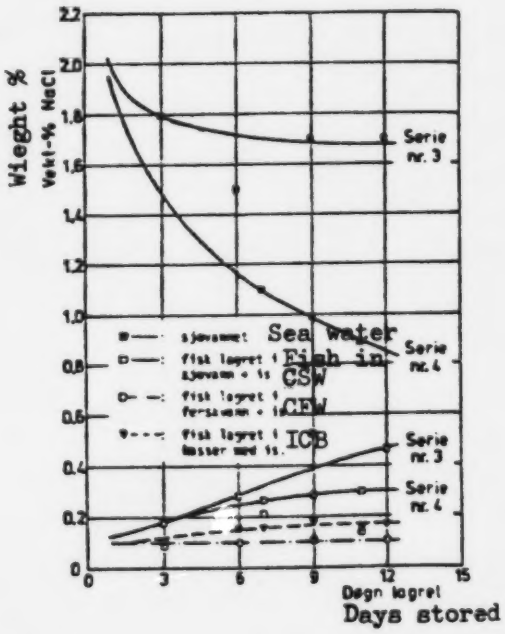


Figure 20.
Measured salinity as a function of storage time, series 3 and 4. The different batches were not separated for CWF and ICB.

* Transl. note: See note page 7.

The salt absorption of the fish in sea water is, of course, affected by the salinity of the water and thus by the ice melting (in the case of fresh-water ice). Figure 20 shows measurements of salinity in series 3 and 4. The small increase in salinity that was measured also in iced fish (ICB), is attributed to the fact that some salt, for practical reasons, was added to the water during the ice production (the figure given was about 0.5 %). For the taste testing, 2.5 % salt was added to the cooking water. The differential tests show that this was enough to camouflage varying salt contents in the fish meat.

7. Conclusion

CSW or CFW in mini-containers are promising methods for transport/storage of fresh fish raw material. The main advantage is that efficiency can be combined with flexibility in the production of raw materials. A well-planned system should result in savings, and at the same time, in an improvement of the average quality of the fish when it is brought ashore.

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